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Saturn, 1959

The authorization of a large rocket vehicle by the Advanced Research Projects Agency in August 1958 and assignment of its development to the Army Ballistic Missile Agency marked the beginning of a series of successful large launch vehicles. In October 1958, the National Aeronautics and Space Agency asked to absorb ABMA's space group, but an agreement was reached two months later for the group to remain with the Army while being responsive to NASA. This decision was to be reconsidered and reversed within a year.

The competition in large launch vehicles between NASA, ARPA, Air Force, and Army, begun in 1958, continued into 1959. The government settled the issue by selecting Saturn as the single large vehicle to serve all needs. Left unresolved until the closing days of 1959, however, was the configuration of Saturn's upper stages.

The competitive actions between government agencies with respect to launch vehicles, the emergence of Saturn, and the bold decision to use liquid hydrogen–oxygen in Saturn's upper stages are related in this chapter.

First National Space Vehicle Plan

With both military and civilian space managers planning launch vehicles during 1958, it became obvious that a single national plan was needed to avoid costly and needless duplication. The task of preparing a unified plan fell to NASA, and by 15 December 1958 Milton Rosen had prepared a draft plan. Although ABMA had briefed NASA on its plans, the review of Rosen's draft revealed that more information was needed. This led to the formation of a "Joint ARPA-NASA Committee on Large Clustered Booster Capabilities" with Rosen and Richard Canright as cochairmen.* The committee listened to seven presentations during the first week of January 1959+ and on the 8th submitted a two-page report, concise and to the point.

Acknowledging that ABMA had "done the most work, [had] explored the problems of clustering more fully, and, in this case, [was] best qualified from an engineering

*Other members: Richard Cesaro and David Young from ARPA; Eldon Hall and Abraham Hyatt from NASA.

+Aerojet-General, Rocketdyne, Convair-Astronautics, Douglas Aircraft, Martin, ABMA, and the Air Force.

standpoint," the report was somewhat critical of the Army organization. Admitting that ABMA's Juno V was feasible, the committee indicated that the time and funds required to solve certain critical problems had been underestimated. Of several possibilities, the committee believed the most practical large vehicle was "a cluster of three Atlases as the first stage and a cluster of three 10-foot diameter stages (liquid oxygen–kerosene at first, liquid oxygen–liquid hydrogen later) as the second stage." The 3-meter oxygen-hydrogen stage referred to was the Centaur. Such a cluster, the committee argued, would be quicker and cheaper to develop than Juno V; but since the latter had a 9-month lead, it should be continued, with limited effort on the cluster initiated as a backup. ARPA and NASA expressed different reasons for having a backup: ARPA wanted limited development started with a second team to broaden national capability; NASA wanted the design of the cluster to proceed to the point of manufacture and be stopped only "if the ABMA configuration is well advanced and shows reasonable promise of success." Both positions reflected a concern over ABMA's ability to perform as promised.

Rosen transmitted the report to Glennan through channels. His boss, Hyatt, added his endorsement, commented favorably on Juno V, and recommended that NASA reopen negotiations to acquire Juno V "as a NASA-sponsored program with ABMA as the developing agency." Silverstein passed the report along without comment, and Glennan took no direct action on it.[1]

Following their work on the committee, Rosen and Eldon Hall prepared the first "National Space Vehicle Program" on 27 January 1959, and it was presented to the National Aeronautics and Space Council the following day. The report was critical of the current launch vehicles—Vanguard, Jupiter C, Juno II, and Thor-Able—calling them hurriedly assembled, not very reliable, and lacking growth potential to meet future needs. A series of general purpose vehicles capable of multiple missions and useful for four or five years was proposed as a means for achieving greater reliability and an orderly progression of payload capability (table 10). Of seven in this series, Atlas-Centaur and Atlas-Hustler (predecessor of Atlas-Agena) were in early stages of development; Scout and Vega were started later in the year, but Vega was cancelled within a few months as being duplicative of Centaur.

Atlas-Centaur had been started by ARPA in August 1958 and was being managed by the Air Force. At the time of the report, NASA was seeking its transfer, and the Air Force was resisting (pp. 200–01). The Centaur stage used two hydrogen-fueled Pratt & Whitney engines for a total thrust of 134 kilonewtons (30000 lb). With an estimated payload of 1800 kilograms, Atlas-Centaur was seen as useful from 1962 through 1966. (In the event, it has proved more useful than anticipated and is expected to continue serving space needs until replaced by the shuttle at the end of the 1970s, or later.)

Juno V was shown in two configurations in the report, differing only in the third stage. The first version would use kerosene-oxygen and the second, hydrogen-oxygen. The 356 kilonewton (80000 lb thrust) engines for the latter were never built.

The largest vehicle described in the report was NASA's Nova, which went through a number of different configurations in various proposals. As envisioned in January 1959, Nova would use four Rocketdyne F-1 engines in the first stage for a total thrust of 27 meganewtons (6 million lb) and one F-1 engine in the second stage. The third and fourth stages would use liquid hydrogen–oxygen and the same proposed 356

TABLE 10.—*Characteristics of Proposed New Launch Vehicles, 1959*

	Stage				
	1	2	3	4	5
Vehicle	Propellants Thrust kN/MN (Thrust lb)	Propellants Thrust kN/MN (Thrust lb)	Propellants Thrust kN/MN (Thrust lb)	Propellants Thrust kN/MN (Thrust lb)	Propellants Thrust kN/MN (Thrust lb)
Scout	Solid 534 kN (120000 lb)	Solid 258 kN (58000 lb)	Solid 58 kN (13000 lb)	Solid 13.3 kN (3000 lb)	
Atlas-Hustler	$RP\text{-}O_2$ 1600 kN (360000 lb)	$N_2H_4\text{-}HNO_3$ 53 kN (12000 lb)	Storable 27 kN (6000 lb)	Solid 2.3 kN (500 lb)	
Atlas-Vega	ditto	$RP\text{-}O_2$ 147 kN (33000 lb)	ditto	ditto	
Atlas-Centaur	ditto	$H_2\text{-}O_2$ 134 kN (30000 lb)	ditto	ditto	
Juno V-A	$RP\text{-}O_2$ 6.7 MN (1500000 lb)	$RP\text{-}O_2$ 890 kN (200000 lb)	$RP\text{-}O_2$ 356 kN (80000 lb)	Storable 89 kN (20000 lb)	Solid 4.5 kN (1000 lb)
Juno V-B	ditto	ditto	$H_2\text{-}O_2$ 356 kN (80000 lb)	Storable 89 or 27 kN (20000 or 6000 lb)	ditto
Nova	$RP\text{-}O_2$ or Storable 27 MN (6000000 lb)	$RP\text{-}O_2$ or Storable 7.6 MN (1700000 lb)	$H_2\text{-}O_2$ 1424 kN (320000 lb)	$H_2\text{-}O_2$ 356 kN (80000 lb)	Storable 89 kN (20000 lb)

Source: "National Space Vehicle Program," 1959.

kilonewton engine as the second version of Juno V. Nova would be about 79 meters high, and NASA saw its application as "transporting a man to the surface of the moon and returning him safely to earth." Four additional stages beyond the five shown would be needed for such a mission with a crew of two or three men. Nova's capability, expressed in terms of earth-orbit payload for comparisons, was 68 metric tons.[2]

Although the first national space vehicle plan was little more than a compilation of Department of Defense and NASA plans, it was the first step towards an integrated program. Juno V evolved into Saturn I, and the very large vehicle NASA called Nova evolved into Saturn V, the vehicle used in the Apollo missions of the 1960s and 1970s.

Saturn Runs into Trouble

Juno V, ABMA's "clustered booster" concept for the first stage of a large launch vehicle, weathered the 28 January 1959 review by the National Aeronautics and Space Council in a show of unanimity. Five days later, the Army proposed to change the name to Saturn. (The Army was naming its major vehicles from Greek mythology, and Saturn followed Jupiter on the list.) The Advanced Research Projects Agency approved the name change the following day. The Army, however, had greater ambitions than a simple name change. On 13 February, Medaris submitted a budget request to meet the schedule of a captive firing by December 1959 and first flight by October 1960. His proposal included live second stages for flights 3 and 4 and a live Centaur stage on the 5th flight.

Medaris's estimates called for increases in FY 1959, 1960, and 1961 funding. He gave two alternatives: one, which he labeled as "dead end," consisted of four vehicles; the second consisted of 16 multistage vehicles. Funding estimates were:

	FY 59	FY 60	FY 61
Plan 1	58.3	75.2	41.1
Plan 2	63.5	120.4	128.0

Medaris, of course, wanted Plan 2, which called for about twice as much funding as previous estimates. Again the Medaris–von Braun team was rolling fast, putting on the pressure for a much greater program than ARPA had envisioned. Saturn was going to serve the needs of both the military and NASA. For the former, the justification was a large communications satellite in a "stationary" (24-hour) orbit.

By June, Pentagon budget planning for Medaris's 16-vehicle program had reduced the FY 1960 amount about 10 percent but almost doubled the FY 1961 amount. These, however, were cut in subsequent reviews, with FY 1960 set at $80 million.

The optimistic budget proposals for Saturn swirling about in the Pentagon indicated a bright future for the vehicle, but storm clouds were gathering. Opposition appeared on 17 March when ABMA presented a systems study for Saturn. Roy Johnson, director of ARPA, wanted the program thoroughly reviewed and appointed an ad hoc committee for the purpose. He also asked for a recommendation on the upper stage for Saturn. The committee worked through April and half of May and studied three candidates for upper stages: Atlas, a one-engine Titan, and a two-engine Titan.

Johnson's committee activity was followed with interest by the Air Force because of anticipated needs for the vehicle. On 13 April, in the midst of committee deliberations, Richard Horner, the Air Force's assistant secretary for research and development, proposed to Johnson that Saturn be used for the Dynasoar space glider and that the Air Force be given project responsibility.* Apparently nothing resulted from this move.

On 19 May, Johnson's committee recommended the two-engine Titan as the second stage for Saturn. A Centaur was proposed as the third stage for NASA missions. Johnson approved these recommendations and notified Medaris.

The proposal to use the Martin-built Titan brought the Air Force back into the picture, for the development of a modified Titan as a Saturn second stage would affect the Air Force Titan program, which was in full swing. Johnson sought to avoid the potential conflict by directing Medaris to coordinate with the Air Force on actions involving the Glenn L. Martin Company. This didn't suit the Army which wanted to contract directly with Martin for the second stage of the Saturn. In July, the Air Force counterproposed that all procurement and technical requirements be channeled through its Ballistic Missile Division, with the Air Force being responsible for systems engineering of the second stage for Saturn. Matters remained at an impasse until ARPA, on 9 July, authorized the Army to contract directly for the second stage. ARPA also stressed the need for Army coordination with the Air Force.[3]

While the storm between the Army and Air Force over responsibility for Saturn's second stage was brewing in June, an even greater threat to the Army and Saturn was in the making. Herbert York was promoted from chief scientist of ARPA to director of defense research and engineering—the Pentagon's top position for R&D. He was responsible for all military R&D and for avoiding unnecessary duplication. It was not long before York fixed a critical eye on the escalating plans for Saturn. He was aware that in late 1958 Deputy Secretary of Defense Donald Quarles and NASA Administrator T. Keith Glennan had urged transfer of both the Jet Propulsion Laboratory and the Army Ballistic Missile Agency's space team to NASA, but "had been shot down in flames by the Army."[4] Medaris, commander of the Army Ordnance Missile Command, von Braun, technical director of ABMA, and Wilbur Brucker, Secretary of the Army, were determined to make the Army the leader for large launch vehicles. The trio were tough opponents; even President Eisenhower believed that the transfer of ABMA to NASA should be made, but he did not interfere with the negotiations. A compromise had been reached in December 1958 to transfer JPL to NASA, but leave ABMA with the Army.

York, a nuclear physicist, professor, and former director of the Livermore Laboratory of the University of California, was accustomed to making his own analyses of roles, missions, and needed systems. In his new job, York decided to try again to get the ABMA vehicle team transferred to NASA. He argued that space exploration, including all manned flight, was the responsibility of NASA; the responsibility for all large launch vehicles for space exploration should be NASA's;

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*Dynasoar was first planned as an airplane boosted to a suborbital altitude followed by skip-glide maneuvers in and out of the atmosphere for maximum range. Later models were to achieve orbit.

von Braun and most of his ABMA team should be transferred to NASA; and the cluster of engines and tanks of Saturn was not the best configuration.

In expanding on his points, York cited the Space Act, his understanding of the President's intentions, and his own belief that "nothing yet suggested by the military, even after trying hard for several years, indicated any genuine need for man in space." York believed that the commitment of the von Braun team to big vehicle development "had been seriously interfering with the ability of the Army to accomplish its primary mission. Whenever the Army was given another dollar, Secretary Brucker put it into space rather than supporting the Army's capability for ground warfare."[5] York's criticism of the Saturn I configuration was based on his analysis which indicated that advanced Titan configurations were superior. He also was convinced that a larger vehicle than Saturn I was needed. These considerations led him to argue that Saturn I, as conceived in mid-1959, was unnecessary and should be cancelled. With these convictions, York made his move in June 1959. ARPA had requested funds for Centaur and Saturn; on 9 June, York informed Johnson that he approved the requested funds for Centaur but not those for Saturn and cited more urgent needs as the reason. He suggested that Johnson might consider shifting funds from other projects for Saturn or, failing this, let the development slip.[6]

With this opening move in his campaign to trim military ambitions in space, York next focused on the Air Force's Titan C proposed by the Glenn L. Martin Company as a launch vehicle for Dynasoar. The first-stage was 4 meters in diameter and was powered by four Aerojet ICBM engines of 667 kilonewtons (150000 lb thrust) each. The second stage was powered by two of the same engines but equipped with larger nozzles for high-altitude operation.[7] On 27 July, York suggested that the Air Force and ARPA should study a common vehicle to meet the requirements of both space missions and Dynasoar. He asked for a report before firm development commitments were made. Two days later, ARPA directed the Army to stop work immediately on using Titan for Saturn's second stage, but soon modified the directive to allow general second stage studies to continue.

Convinced that Saturn was "much bigger than any purely military oriented requirements demanded,"[8] York found that a similar view was held by George Kistiakowsky, the President's science advisor, and others who had reviewed military satellite requirements in particular and had concluded that more small "stationary" communications satellites were better than a few large ones. This was a blow to the main military justification for Saturn. York discussed his analysis and conclusions with Secretary of Defense Neil McElroy and then sent Roy Johnson at ARPA this message:

> I have decided to cancel the Saturn program on the grounds that there is no military justification therefor, on the grounds that any military requirement can be accommodated by Titan C as proposed by the Air Force, and on the grounds that by the cancellation the Defense Department will be in a position to terminate the costly operation being conducted by ABMA.[9]

The big questions facing Johnson, if he were to rebut York's arguments, were: Could Titan C accomplish the missions in the military's ten year plan, be ready as soon as Saturn, and be built at lower cost than Saturn? If the answers to these were affirmative,

he would have to agree with York. Johnson went into a huddle with his staff. Meanwhile, he informed McElroy that if York's assertions were correct, he would not oppose the cancellation of Saturn. He also proposed that Saturn and ABMA be transferred to the Air Force.[10] This was apparently a last-ditch effort to get the Air Force's help in saving Saturn.

Secretary of the Army Brucker, who had successfully fought Quarles and Glennan to keep ABMA in late 1958, was outraged. Years later York recalled being summoned by Brucker and threatened with dire consequences, but remained firm.[11]

Transfer of Saturn and ABMA to NASA

York's questioning the military need for Saturn forced the issue and the Air Force, Army, ARPA, and NASA had to reconsider and defend their needs for large launch vehicles. He appointed a committee to review the three vehicles under consideration—Titan C, Saturn, and Nova—with himself and Hugh Dryden, NASA deputy administrator, as co-chairmen.* At the outset, the committee agreed on one point: only one large vehicle should be developed by the government. The presentations on Saturn were made by Canright and House of ARPA and Hardeman of ABMA. Some of the committee members recommended further studies to better define the Saturn upper stages. From committee deliberations, Saturn I emerged as the winner. Titan C was shelved, and Nova was too far in the future to be considered competitive to Saturn I.[12]

York concurred with his committee's recommendation to continue Saturn development. Soon after the committee meeting, he began negotiating with NASA Administrator Glennan for transferring ABMA to NASA. He had Secretary of Defense McElroy's support on this, because McElroy wanted to relieve the Army of the big vehicle program.[13]

In September 1959, there were two issues with respect to Saturn: the second stage configuration and the transfer of the ABMA Saturn development team to NASA. ARPA's stop order on second stage contracting, issued at the end of July, was still in effect, and ARPA had been allocating FY 1960 funds to ABMA on a monthly basis since July, pending resolution of the fate of Saturn.

On 23 September 1959, ARPA responded to the York-Dryden committee suggestions to restudy the second stage by requesting ABMA to make such a study. In the meantime, the transfer of the ABMA Saturn team had come to a head. The top officials of the Department of Defense and NASA were in agreement by October; what remained was convincing von Braun. A meeting had been set with the President on 21 October to formalize the transfer, and the night before, Glennan and Horner met with von Braun in a Washington hotel room.[14] Even at that late hour, von Braun had some grave misgivings about the whole plan. His reluctance to transfer to NASA was not caused by any dislike for the new civilian space agency, the creation of which he had favored. However, several earlier discussions with Glennan had led him to doubt

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*Other members were Richard Horner, NASA associate administrator; Abe Silverstein, NASA director of space flight development; Richard Morse, director of Army research and development; and Joseph V. Charyk, assistant secretary of the Air Force for research and development.

whether the fledgling agency was ready and able to absorb the entire ABMA team of several thousand people. Von Braun believed that a transfer to NASA of only a portion of his team would seriously jeopardize the continuing development of the Saturn rocket, as well as the orderly completion of unfinished work for Jupiter and the Army's new Pershing missile.[15]

Glennan and Horner, however, convinced von Braun that NASA would support him all the way. The next day the transfer of von Braun's team to NASA was formalized. DoD and NASA officials met with President Eisenhower, who approved the transfer by executive order, subject to the approval of Congress. The transfer became effective on 15 March 1960.

The Gathering Storm over Saturn Configurations

The agreement of 21 October 1959 transferring Saturn and its development team to NASA left the upper stage configuration as the major unresolved issue. The proposal to use a Titan as the second stage had been delayed by the ARPA directive in July. At the time of the transfer agreement, ABMA was restudying Saturn upper stages. This study was assigned to a vehicle analysis group headed by H.H. Koelle and assisted by Francis L. Williams.

Koelle, like von Braun and Ehricke, had become interested in rockets at an early age. A German pilot during World War II, he was shot down by American antiaircraft fire in early 1945. Continuing his interests in rockets after the war, he founded the German Space Society in 1948. Von Braun brought him to the United States in 1955; Koelle specialized in analysis, planning, and designing advanced space vehicles. His large group was assisted by aerospace contractors who also had sizable staffs of advanced design specialists.

In 1959, Koelle's group participated in the Army's bid for a role in manned spaceflight. In March, the Army high command authorized the study of a space project called "Project Horizon," the establishment of an Army lunar outpost which proponents referred to as "high ground."[16] The Project Horizon study, completed in June, is an example of very advanced planning; it is of interest here because of the Saturn configurations proposed and some of ABMA's mid-1959 thinking about the use of liquid hydrogen. Launch vehicles for the lunar mission were designated Saturns I and II. The study also considered a much larger vehicle of 53 meganewtons (12 million lb of thrust) using eight F-1 engines and hydrogen-oxygen upper stages, but concluded that this giant vehicle was not needed for the basic mission.

Saturn I for Project Horizon (fig. 55) had three stages. The first was a clustered tank and engine stage using eight Rocketdyne H-1 engines of 837 kilonewtons (188 000 lb of thrust) each, with kerosene and oxygen as propellants. The second stage was essentially a first-stage Titan I, 3 meters in diameter and powered by two Aerojet LR-89 engines with a thrust of 841 kilonewtons (190 000 lb) each, also using kerosene and oxygen. The third stage was a Centaur powered by two Pratt & Whitney RL-10 engines of 67 kilonewtons (15000 lb thrust) each, using liquid hydrogen–oxygen. Saturn I was essentially the same configuration ABMA was advocating when work was stopped by the July ARPA directive.

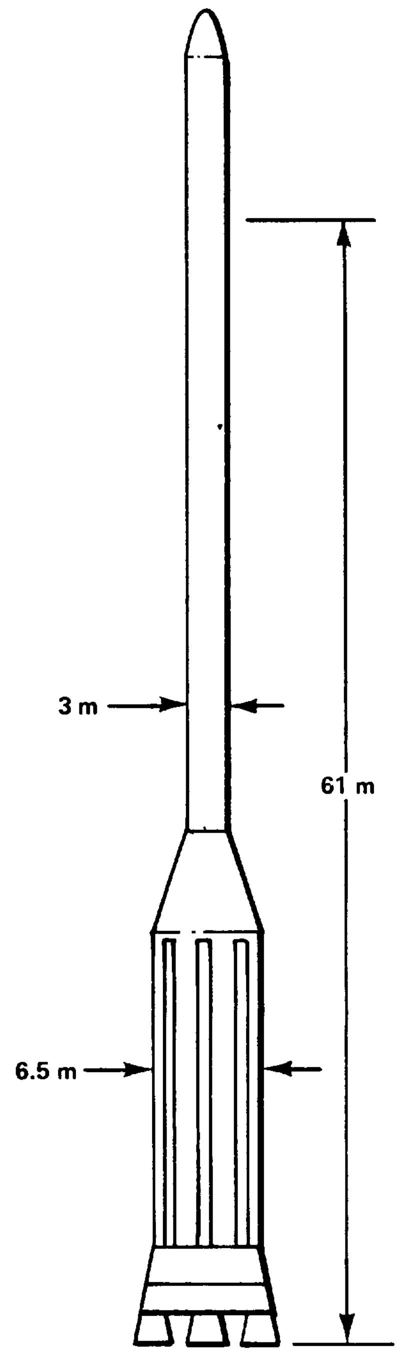

Fig. 55. Saturn I as sketched for Project Horizon by the Army Ballistic Missile Agency, 9 June 1959. The first stage used a cluster of tanks and eight engines with a total thrust of 6.7 MN (1.5 million lb); the second stage used two of the same engines burning RP (kerosene) and oxygen. The third stage was a Centaur powered by two hydrogen-oxygen engines.

Saturn II was a second generation vehicle with four stages. The first stage was similar to Saturn I but with uprated engines to provide a total thrust of 9 meganewtons (2 million lb). The second stage was powered by two new proposed engines of 2.2 meganewtons (500 000 lb thrust) each, using liquid hydrogen–oxygen. The third stage was powered by two other new engines of 445 kilonewtons (100 000 lb thrust) each, also using liquid hydrogen–oxygen. The fourth stage was powered by a single engine of the same type as in the third stage. Saturn II, therefore, would use liquid hydrogen–oxygen in all of its upper stages.[17]

In subsequent months, ABMA became much more conservative in its thinking about Saturn upper stages and, ironically, resisted NASA proposals to proceed with liquid hydrogen–oxygen. The reasoning of both parties and the confrontation that was barely avoided complete our story.

NASA had participated in a May 1959 decision recommending the Titan-based second stage for Saturn, which had been stopped by ARPA in July. After the September meeting of the York-Dryden committee on large vehicles, Eldon Hall, Francis Schwenk, and Alfred Nelson began to study Saturn and upper stage configurations. Hall was a leading analyst of flight propulsion and vehicles during his 15 years at the NACA Lewis laboratory. Schwenk was also a propulsion systems analyst who had worked at the Lewis laboratory for eight years before coming to NASA headquarters in 1958. Nelson had been a propulsion analyst at Wright Field for 17 years before joining the group in March 1959.

Two days after the October agreement to transfer Saturn to NASA, Hall sent Silverstein the results of the analysis his group had been making. Among his conclusions: Saturn was basically a good vehicle and could be uprated by using a 4.5 neganewton F-1 engine to replace four of the eight H-1 engines; and by suitable choice of upper stages, development cost could be minimized. Hall recommended that Saturn development be continued and included a phased program (table 11).

Hall's analysis included the new proposed hydrogen-oxygen engine of 668 kilonewtons (150 000 lb thrust) under study by a NASA-DoD group during the year. By agreement with ABMA, the engine was changed to 890 kilonewtons (200 000 lb); it evolved into the J-2 engine by 1960. The NASA B-1 configuration (table 11) was essentially the same as ABMA had proposed as Saturn I of Project Horizon the previous May. Hall was aware of the configuration studies of Koelle and Williams and informed Silverstein that the C-1 configuration in his analysis was similar to the advanced Saturn proposed by ABMA.[18]

The analyses of Saturn by Hall, Schwenk, and Nelson reflected a tradition of NACA and Air Force laboratories. Independent analyses of propulsion systems were not only a means for advancing new concepts, but also for verifying or challenging claims by others. Analyses form the basic framework for interpreting experimental results; it was as routine as tying one's shoe for Silverstein and Hall to do their own analyses of Saturn configurations. This, however, was something new in the experience of ABMA in dealing with headquarters people.

At the end of October, Hall had participated with Abe Hyatt and Adelbert Tischler in a technical survey of ABMA vehicles and attended a meeting in the Pentagon on Saturn configurations. From these meetings, he prepared a table of various Saturn configurations proposed by ABMA, which is reproduced as table 12.[19] The next day

TABLE 11.—*NASA Saturn Configurations, 23 October 1959*

Configuration	Stage	Name/dia., m	Propellants	No./Type Engine	Stage thrust kN, MN (k, M lb)
B-1	1	Saturn	RP-O_2	8/H-1	6.7 MN (1.5 M)
	2	Titan with thicker skin/3	RP-O_2	2/LR-87	1.8 MN (400 k)
	3	Centaur as proposed for Atlas	H_2-O_2	2/RL-10	134 kN (30 k)
B-2	1	Same as B-1			
	2	High-energy stage	H_2-O_2	2/new 667-kN engines	1.3 MN (300 k)
	3	Enlarged Centaur	H_2-O_2	2/uprated RL-10	greater than 6.7 MN (1.5 M)
C-1	1	Uprated Saturn	RP-O_2	1/F-1 & 4/H-1	not specified
	2	High-energy stage	H_2-O_2	4/uprated 667-kN engines	greater than 2.7 MN (600 k)
	3	Same as Stage 2 of B-2			
	4	Same as Stage 3 of B-2			

he fixed a critical eye on the ABMA configurations and compared them with his own.[20] In the months since June, ABMA had abandoned the use of a Titan I for the second stage because its 3-meter diameter made the vehicle too long and slender, which increased bending loads from aerodynamic forces. Instead, a diameter of 5.6 meters was favored for the second and third stages in the first two models of proposed Saturns (B-1 and B-2, table 12); the fourth stage of a later model (C) went to the same diameter. A feature of the first three ABMA configurations (B-1, B-2, B-3) was the use of either existing engines or engines under development. This would supposedly shorten development time, as engines traditionally took longer to develop than airframes. For this advantage, ABMA was willing to pay a penalty in size and payload. The second stage of the first three configurations used kerosene and liquid oxygen as propellants. NASA, on the other hand, wanted to start development of a 668 kilonewton (150 000 lb thrust) hydrogen-oxygen engine immediately and use it in the second stage of their second model (NASA B-2). ABMA was concerned about bending problems and the need to develop a new, large, hydrogen-oxygen engine for the second stage. NASA was concerned that ABMA's first configuration (ABMA B-1) would cost so much that the development of the large hydrogen-oxygen engine would be seriously delayed and the advanced configurations might never be attained. Hall noted that the second stage of ABMA's first configuration (B-1) was in the Titan C class, yet the payload capability was less than NASA's B-2, for an equal number of stages. Hall became convinced that the ABMA approach was much less than optimum.

TABLE 12.—*Summary of ABMA Saturn Configurations, November 1959*

Config-uration	Stage	Name/dia., m	Propellants	No./Type Engine	Stage thrust kN, MN (k, M lb)
	1	Saturn	RP-O_2	8/H-1	6.7 MN (1.5 M)
Initial	2	Titan/3	RP-O_2	2/LR-87	1.8 MN (400 k)
	3	Centaur/3	H_2-O_2	2/RL-10	134 kN (30 k)
	1	Saturn	RP-O_2	8/H-1	6.7 MN (1.5 M)
B	2	Titan/4.1	RP-O_2	2/LR-87	1.6 MN (360 k)
	3	Centaur/3	H_2-O_2	2/RL-10	134 kN (30 k)
	1	Saturn	RP-O_2	8/H-1	6.7 MN (1.5 M)
B-1	2	/5.6	RP-O_2	4/LR-87	3.9 MN (880 k)
	3	/5.6	H_2-O_2	4/RL-10	356 kN (80 k)
	4	/3	H_2-O_2	2/RL-10	178 kN (40 k)
	1	Saturn	RP-O_2	8/H-1	8.9 MN (2 M)
B-2	2	/5.6	RP-O_2	4/LR-87	3.9 MN (880 k)
	3	/5.6	H_2-O_2	6/RL-10	534 kN (120 k)
	4	/3	H_2-O_2	2/RL-10	178 kN (40 k)
	1	Saturn	RP-O_2	8/H-1 or 4/H-1 + 1/F-1	8.9 MN (2 M)
B-3	2	/5.6	RP-O_2	4/LR-87	3.9 MN (880 k)
	3	/5.6	H_2-O_2	2/new	1.3 MN (300 k)
	4	/5.6	H_2-O_2	4/RL-10	356 kN (80 k)
	1	Saturn	RP-O_2	8/H-1	6.7 MN (1.5 M)
B-4	2	/5.6	H_2-O_2	4/new	2.7 MN (600 k)
	3	/5.6	H_2-O_2	2/new	1.3 MN (300 k)
	4	/5.6	H_2-O_2	4/RL-10	356 kN (80 k)
	1	Saturn	RP-O_2	8/H-1 or 4/H-1 + 1/F-1	8.9 MN (2 M)
C	2	/6.5	H_2-O_2	6/new	4.0 MN (900 k)
	3	/5.6	H_2-O_2	2/new	1.3 MN (300 k)
	4	/5.6	H_2-O_2	4/RL-10	356 kN (80 k)

Source: "Report on Technical Survey of ABMA Activities," Eldon W. Hall, NASA headquarters, 2 Nov. 1959.

Hall got strong support for his views on hydrogen-oxygen for upper stages in a separate but concurrent action. In October 1959, Homer Joe Stewart, NASA's director of program planning and evaluation, wrote a classic memorandum comparing the performance of Atlas-Vega, Atlas-Agena B, and Atlas-Centaur. Differing only in upper stage configurations, Vega used kerosene-oxygen in its upper stage; Agena B, UDMH and nitric acid; Centaur, hydrogen-oxygen. Stewart concluded that since the payloads of Atlas-Vega and Atlas-Agena B were the same, one should be cancelled; subsequently, Vega was. Regarding hydrogen-oxygen, Stewart stated:

> Each oxygen-hydrogen stage that is substituted for a conventional propellant stage in a multistage vehicle will increase the payload for a deep space mission two or more times. The figure may be about six times for a marginal conventional propellant system (ratio of payload to first-stage gross weight 0.002). A figure of two to three times is a reasonable generalization. Therefore, substituting oxygen-

hydrogen for conventional propellants in two stages of a multistage booster vehicle would increase the payload four to nine times.[21]

While Hall was studying Saturn configurations, Richard Horner, NASA's general manager, initiated an action on ABMA's transfer that provided the mechanism for resolving the issue of Saturn's upper stage configuration.

Saturn Vehicle Team

Following the decision to transfer Saturn to NASA, Richard Horner and Herbert York worked out an agreement for NASA to exercise technical guidance of the project until the formal transfer took place. The agreement provided for a Saturn committee, consisting of NASA and DoD members with a NASA chairman, to provide "advice and assistance" in technical matters. The first and most pressing technical decision was on the upper stages, and Horner requested Silverstein to establish a Saturn Vehicle Team "to prepare recommendations for the guidance of the development and, specifically, for selection of upper stage configurations." Horner made his request on 17 November and wanted the recommendations within thirty days. Silverstein lost no time in getting his team organized.[22] It consisted of:

Abe Silverstein, Chairman	NASA
Col. Norman C. Appold	USAF
Abraham Hyatt	NASA
Thomas C. Muse	DDR&E
G. P. Sutton	ARPA
Wernher von Braun	ABMA
Eldon W. Hall, Secretary	NASA

A brief review of the member's attitudes towards hydrogen is in order.

Silverstein's strong advocacy of hydrogen as a high-energy fuel for aircraft and rockets was well known. Research on hydrogen as a rocket fuel at the NACA Lewis laboratory had been under his direction since 1950. He had initiated a large program on hydrogen for high-altitude aircraft in 1955 and strongly supported more work on hydrogen for rockets. He was familiar with Hall's Saturn studies showing the advantages of using hydrogen-oxygen in the upper stages and was convinced this was the way to go.

Colonel Appold had been the Air Force's manager of the Suntan project using hydrogen for a high-altitude aircraft. In the spring of 1958, he had supported proposals that led later to the initiation of Pratt & Whitney's development of a hydrogen-oxygen rocket engine for Centaur. A large amount of money had been spent on Suntan; and after its cancellation, Appold remained interested in obtaining tangible returns on that investment in technology and facilities. As the only Air Force member of the team, however, Appold had other concerns. The Air Force believed that the Glenn L. Martin Company had its hands full with the Titan ICBM program and took a very dim view of ABMA vehicle proposals using modified Titans, which could interfere with Martin's

work on ICBMs.[23] On the other hand, the Air Force was mildly interested in a two stage Saturn as a possible launch vehicle for an advanced Dynasoar—an application that did not need high-energy propellants. Appold, therefore, represented somewhat conflicting views within the Air Force.

Abe Hyatt came from Russia as a small boy, served in the marines during World War II, and rose to chief scientist of the Navy's Bureau of Aeronautics before joining NASA as a flight vehicle and propulsion expert in 1958. He headed launch vehicle and propulsion at NASA headquarters and reported to Silverstein; Eldon Hall worked for him. The three were in agreement on the need to use hydrogen in the upper stages of Saturn from the outset.

Thomas C. Muse worked eleven years as an aeronautical engineer at NACA's Langley laboratory and Douglas Aircraft before joining the Secretary of Defense's staff as an aeronautics expert in 1950. He was neutral with respect to high-energy fuel preferences but recognized their value.[24]

George P. Sutton, chief scientist of ARPA, was the author of the standard rocket propulsion textbook widely used in the United States since it first appeared in 1949. He came to ARPA from Rocketdyne and, like Muse, was neutral on the subject of liquid hydrogen. He was, however, a strong advocate for ARPA interests.

At the time the Saturn Vehicle Team was organized, Wernher von Braun was cold to the idea of using liquid hydrogen. While it is true that his organization proposed Saturn configurations using liquid hydrogen, the early versions would use hydrogen only in the third stage; this was the Centaur and it was being developed by someone else. Of more immediate concern to von Braun was getting confirmation of his plans for the first stage from his new boss, NASA, and settling the long-delayed decision on the second stage. Having been convinced that a cluster of existing engines made sense for early development of the Saturn first stage, he was now equally convinced that a smaller cluster of the same engines made sense for the second stage as well. He could concentrate on building and flight-testing the first two stages, useful for earth-orbital missions, while General Dynamics–Astronautics developed the hydrogen-fueled Centaur as a potential third stage for Saturn. During the Centaur development, already a year old, there would be time to "work out the bugs" in using hydrogen before von Braun had to face the task of adapting it to a third stage.[25] His plan was logical but flawed, as we shall see.

Von Braun's negative attitude towards hydrogen extended far into his background. About 1937, he had observed attempts by Walter Thiel to operate a small rocket engine with liquid hydrogen at Kummersdorf, and the greatest impression he retained was of the numerous line leaks and difficulties of handling liquid hydrogen. It left him with a healthy respect for the safety and fire hazards involved. This attitude would be helpful later in the successful development of the Saturn V, but at the moment was a major roadblock to his acceptance of liquid hydrogen for Saturn I's second stage. At Fort Bliss in the 1940s, von Braun's group had considered a variety of propellants for possible use in the V-2 for a high-altitude sounding mission. The V-2 structure and engine were so heavy that substituting a very low-density fuel like hydrogen would have resulted in poor performance. Krafft Ehricke, who worked for von Braun at Fort Bliss and later at Huntsville, recalls von Braun's objections to low-density propellants.

So does Richard Canright, who wrote a paper on the importance of exhaust velocity and density during that period.[26]

Eldon Hall, the team's secretary, was the sharp analyst who had worked closely with Silverstein since 1955 on the application of liquid hydrogen for high-altitude aircraft and was intimately acquainted with its problems. He had studied very light structures. He had extensive analytical experience in both aircraft and rocket performance. Like Silverstein, he was familiar with liquid-hydrogen research at the Lewis laboratory and had confidence in its practicality. Hall's earlier analyses of Saturn configurations had convinced him that to keep vehicle mass within reasonable limits, the upper stages should use high-energy propellants; and of all the candidates, the combination of liquid hydrogen–oxygen was the closest to practical application.[27] He and Silverstein shared a common understanding and view, and Hyatt—sandwiched between them at NASA—had been persuaded to their view.

Silverstein, therefore, had three working group members favoring his view: Appold, Hyatt, and Hall. Von Braun was the chief opponent—the man who had to be convinced. Silverstein knew that winning von Braun to his view was essential to his and NASA's plans. Von Braun probably was unaware of the extent of NASA's Saturn studies or the intensity of their views on its upper stages. Certainly von Braun wanted to establish good working relationships with his new organization, and he wanted to get on with the job of building large launch vehicles. Although the stage was set for a confrontation, nobody wanted it. Silverstein drew upon all of his skill as chairman to guide the discussions, and he counted on Hyatt and Hall to be strong advocates for his own views. The three met during the course of the team's work to discuss how best to persuade von Braun to their view.[28]

The vehicle team met for the first time on Friday, 27 November. It met four more times and concluded its work on 15 December, with oral and written reports to the NASA administrator.[29]

The first meeting was devoted entirely to briefings: C. Beyer on management aspects of Saturn, E. M. Cortright on NASA missions for Saturn, R. Smith on the Dynasoar program, Wernher von Braun and H. H. Koelle on the technical aspects of the ABMA Saturn systems study, F. L. Williams on the development and funding of the same study, and J. C. Goodwyn on ARPA's evaluation of the study. Upper stages were discussed the next day. Von Braun stressed the importance of an immediate decision and the need to use second stages of 5.6 meters in diameter to lessen bending loads. ABMA was now opposed to using the 3-meter-diameter Titan I as the Saturn second stage, but still favored a modified Titan of larger diameter using RP-oxygen engines.

By the second meeting, the team had agreed on a report outline and assignments of members to write the first five sections, two of which were critical. One of these, about possible Saturn configurations and their performance, was assigned to Koelle of ABMA and Hall and Schwenk of NASA headquarters. The other, on evaluation of Saturn configurations, was assigned to Goodwyn of ARPA, Williams of ABMA, and Hall of NASA. Conclusions and recommendations remained the responsibility of the entire team. The subgroups assigned to prepare the five sections began their work while also participating in meetings of the vehicle team as a whole.

By 3 December a consensus had emerged on one point: to recommend the Saturn first stage under development at ABMA. Attention then shifted to upper stage configurations. A short pitch for solids got little support; von Braun was strongly opposed, because that would combine the handling difficulties of both liquids and solids. Muse argued against a program involving many vehicle changes in favor of going directly to the final desired configuration. Hall noted in the minutes that hydrogen's energy was needed in the upper stages for most missions—although not for Dynasoar—so hydrogen problems had to be faced and solved. Since Dynasoar had an alternative launch vehicle under study, why not go directly to a hydrogen upper stage for Saturn? The problem was really the second stage engine. One solution was to use a stage powered by a cluster of four Pratt & Whitney Centaur engines uprated to a thrust of 89–111 kilonewtons (20000–25000 lb) each. At the meeting the next day, von Braun was still not convinced about using hydrogen-oxygen in the second stage. He pointed out that no brand new rocket engine had ever been developed in less than four years and that the development of a liquid hydrogen–liquid oxygen engine more than ten times larger than the Pratt & Whitney engine might take even longer. For this reason, he was not willing to abandon conventional fuels. He also wanted to determine in greater detail the problems with hydrogen-oxygen.

Von Braun expressed concern over aerodynamic heating of liquid hydrogen which required encapsulation of the Centaur stage during flight through the atmosphere—a problem he felt had not been adequately studied for a hydrogen second stage for Saturn. Tank loading and venting problems on the launch pad, with their attendant fire hazards, were other concerns.

By 10 December, Hall had prepared a working draft of the report which contained a recommendation that the second stage be powered by a cluster of four Pratt & Whitney RL-10 (hydrogen-oxygen) engines uprated to 89 kilonewtons (20000 lb of thrust) each. The stage diameter was 5.5 meters and length, 10.7. There was also a recommendation for Centaur as the third stage and initiation of development of a hydrogen-oxygen engine of 667 to 890 kilonewtons (150000 to 200000 lb of thrust) for later Saturn stages.

It was inevitable that at some point during the work of Silverstein's team and its subgroups, the ABMA and NASA representatives would clash head on. Frank Williams, in Koelle's ABMA group on future projects, recalled that the ABMA team was initially so opposed to the use of hydrogen that plans were made "to confront Silverstein with not *no* but *hell no*!" Williams worked hard assembling a four-hour presentation containing great technical detail including cost, probability of success, and impact on Saturn I development schedule, and came to Washington all charged up "to shoot Silverstein out of the saddle." Silverstein was the first to speak and, according to Williams, gave a generalized argument for hydrogen with no technical details: this is the challenge for the long haul; hydrogen is the best fuel; sure it has problems but we can solve them if we dedicate ourselves. Williams considered it a talk along philosophical rather than technical lines and was eager to spring up in rebuttal after von Braun introduced him. To Williams's open-mouthed astonishment, von Braun said, in effect: Abe has a good point. Williams never got the chance to present his arguments. He, not Silverstein, had been "shot out of the saddle"—by his own boss.[30]

Eldon Hall's group at NASA headquarters tangled with Koelle's advanced design group at ABMA on another occasion, which proved to be decisive. The NASA

headquarters analysts were using their slide rules to calculate vehicle performance whereas ABMA analysts used a complex program requiring large computer runs. It was not an equal match, but the NASA headquarters analytical group (Hall, Schwenk, and Nelson) had a great deal of experience and judgment. They had noticed that all the Saturn configurations showing promise had at least one upper stage using hydrogen-oxygen. Configurations that used only "conventional" (lower performance) propellants had total masses up to twice as great as those using hydrogen-oxygen stages. The configuration favored by ABMA at one point used four ICBM engines burning RP-oxygen to power the second stage and a modified hydrogen-oxygen Centaur as the third stage. Hall calculated that, by simply replacing the RP-oxygen second stage with the Centaur alone, the resulting two-stage vehicle would lift nearly as much payload to earth orbit as the three-stage ABMA configuration. Hall so argued at one meeting and von Braun considered it incredible. He telephoned Huntsville, where the computer was kept busy all night. The following morning, ABMA telephoned von Braun that Hall was right—the payload without the RP-oxygen stage was indeed close to that with it![31] It was a powerful and convincing argument for the use of high-energy upper stages. This, and the persuasive arguments of Silverstein, convinced von Braun that hydrogen-oxygen for all the upper stages of Saturn was the way to go.

The meeting of 14 December was spent on the proposed report. Sutton questioned the payload figures and wanted to wait for the final "official values" from ABMA, but time was running out. He also argued unsuccessfully for considerably more study before making specific recommendations and questioned the wisdom of omitting a large diameter Titan I as a possbile second stage. By then, however, the von Braun team not only opposed the modified Titan I, because of its high bending stresses, but now strongly supported hydrogen-oxygen in all upper stages. Oswald Lange, representing von Braun, successfully argued that the large diameter Titan I with RP-oxygen was a "dead end" course, and the report so indicated. On 15 December the Saturn Vehicle Team endorsed the recommendation that all upper stages of Saturn be fueled with hydrogen and oxygen. Silverstein, with help from Hall, quickly prepared the final report which bears the same date. The unanimous decision for hydrogen in Saturn's upper stages was a victory for the skillful chairman and his quiet but sharp secretary.

Saturn Development Plan

The report of the Saturn Vehicle Team on 15 December 1959 gave lunar and deep space missions (4500 kg payload) first importance; "stationary" 24-hour equatorial orbit missions second priority; and manned spacecraft missions in low earth orbit (e.g., Dynasoar) third. Five recommendations were made regarding launch vehicles for these missions. A plan was needed for the orderly development of a series of vehicles of increasing payload capability, with emphasis on reliability. All upper stages would use liquid hydrogen–oxygen. The first of the vehicle series should be configuration C-1 (table 13). Fourth, development of a new hydrogen-oxygen rocket engine with a thrust of 668–890 kilonewtons (150000–200000 lb) should begin immediately, along with design studies of stages using it. Finally, a funding plan as prepared by ABMA for vehicle development was recommended.[32]

TABLE 13.—*Possible Saturn Configurations, December 1959*

Vehicle	Stage 1	Stage 2	Stage 3	Stage 4
A-1	$RP\text{-}O_2$ 8 H-1 cluster	$RP\text{-}O_2$ Titan 3 m dia.	$H_2\text{-}O_2$ Centaur 3 m dia. 2 × 67 kN (15000 lb)	
A-2		Cluster of IRBM engines	$H_2\text{-}O_2$ Centaur 3 m dia. 2 × 67 kN	
B-1		$RP\text{-}O_2$ 5.6 m dia. 4 H-1 type	$H_2\text{-}O_2$ 5.6 m dia. 4 × 67–89 kN (15000–20000 lb)	$H_2\text{-}O_2$ Centaur 3 m dia. 2 × 67 kN
C-1		$H_2\text{-}O_2$ 5.6 m dia. 4 × 67–89 kN	$H_2\text{-}O_2$ Centaur 3 m dia. 2 × 67 kN	
C-2		$H_2\text{-}O_2$ 5.6 m dia. 2 × 668–890 kN (150000–200000 lb)	$H_2\text{-}O_2$ 5.6 m dia. 4 × 67–89 kN	$H_2\text{-}O_2$ Centaur 3 m dia. 2 × 67 kN
C-3	$RP\text{-}O_2$ 8.9 MN cluster (2 million lb)	$H_2\text{-}O_2$ 5.6 m dia. 4 × 668–890 kN	$H_2\text{-}O_2$ 5.6 m dia. 2 × 668–890 kN	$H_2\text{-}O_2$ 5.6 m dia. 4 × 67–89 kN

Source: Saturn Development Team, "Report to the Administrator on Saturn Development Plan," 15 Dec. 1959.

Of six vehicle configurations considered, only three were recommended (those with "C" designations, table 13). Combinations of only three hydrogen-oxygen upper stages would serve for all three vehicles in a "building block" approach proposed by Hall (figs. 56, 57).[33] The two engines proposed for these upper stages were the Pratt & Whitney RL-10, part of the legacy of the Suntan project, and a new and larger engine which later became the J-2.

The Saturn Vehicle Team presented the results in a meeting with T. Keith Glennan, NASA administrator; Hugh L. Dryden, deputy administrator; and Richard Horner, associate administrator; and its recommendations were approved. On 29 December, Horner discharged the vehicle team and replaced it with a new Saturn committee that he and Herbert York had agreed would be useful in technical guidance for Saturn during the interim period, before ABMA and the Saturn were formally transferred to NASA the following March.[34] By this time, NASA had split its space effort into two parts with Silverstein heading the office of spaceflight programs, concerned chiefly with

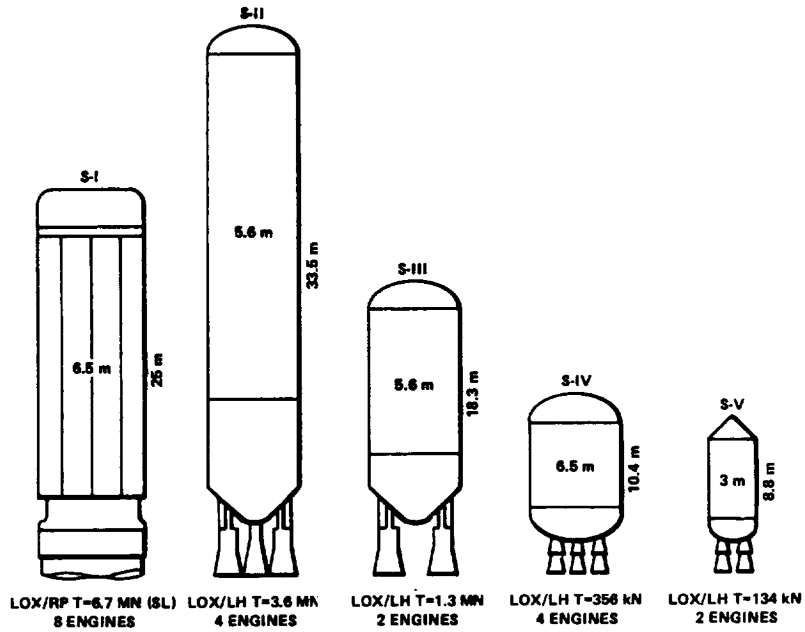

Fig. 56. Saturn "building block" stages recommended for a series of launch vehicles by the Saturn vehicle team, December 1959.

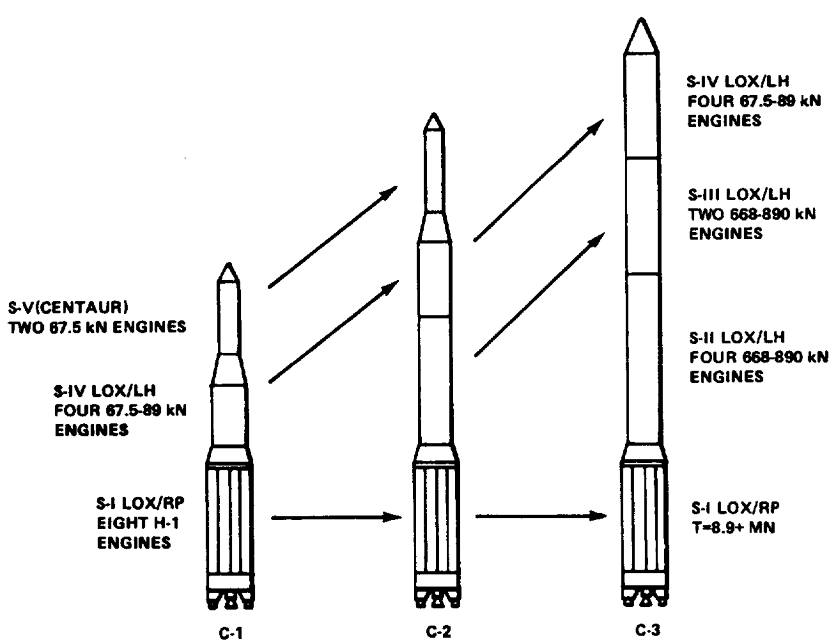

Fig. 57. Saturn configurations recommended by the Saturn vehicle team, December 1959.

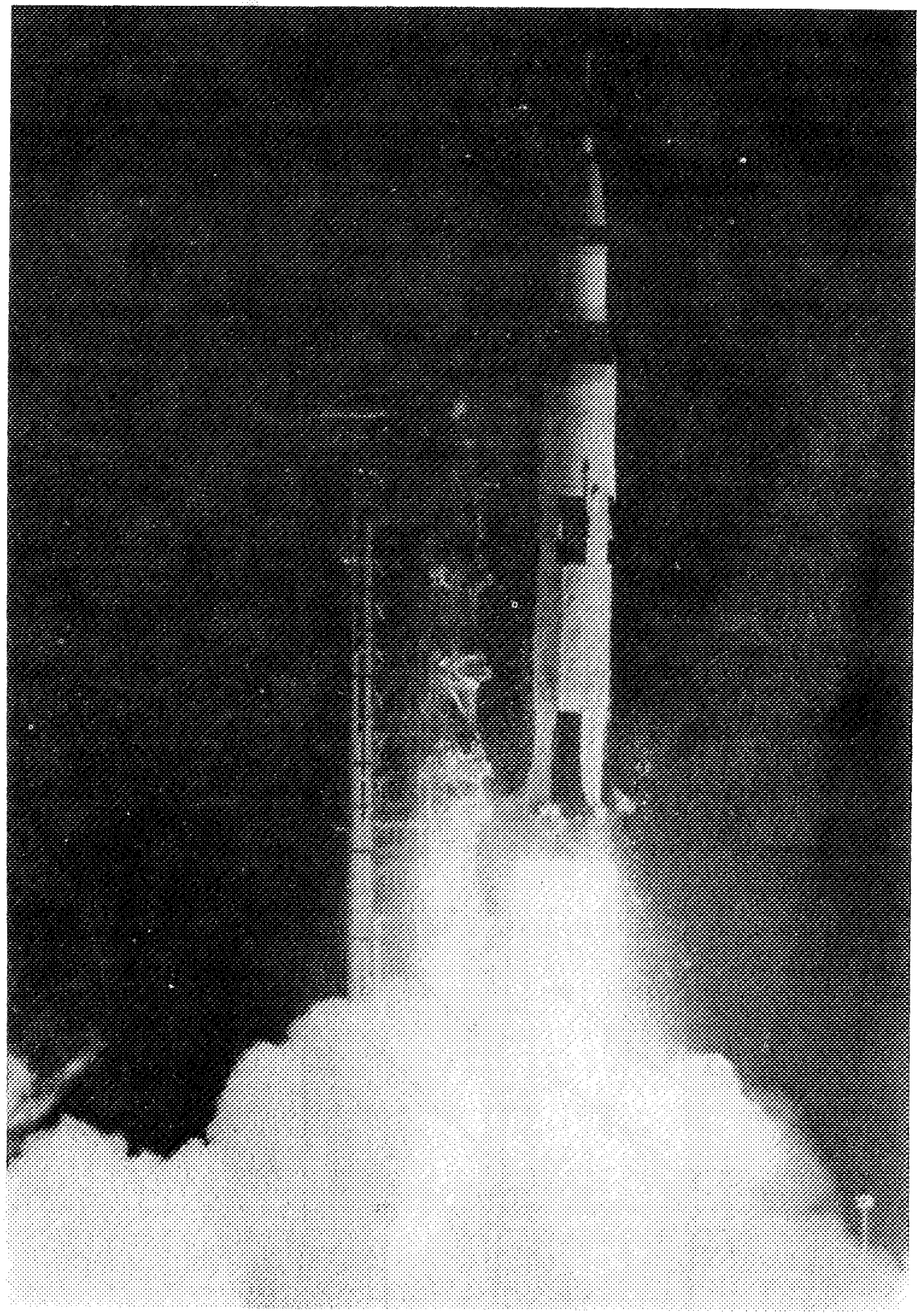

Fig. 58. Saturn V, the Apollo launch vehicle, 10 m in diameter and 111 m tall with the Apollo spacecraft. First launched in 1967, Saturn V used liquid hydrogen–oxygen in its two upper stages.

space missions and payloads, and Maj. Gen. Don R. Ostrander heading the newly created office of launch vehicle programs, responsible for the launch vehicles and propulsion development and operations.

During the next two years, Saturn configurations were restudied as part of the national commitment in 1961 for a manned lunar landing, but one basic concept established by Silverstein did not change: the use of hydrogen in all Saturn upper stages. The work of Silverstein, Hall, and the other members of the Saturn Vehicle Team in taking a bold stand in choosing to use liquid hydrogen for Saturn was one of the major decisions that made the great manned spaceflight events of the 1960s and 1970s possible.